

# Steam Locomotives in the History of Technology of Mexico

C. López-Cajún

Universidad Autónoma de Querétaro, Querétaro, México  
cajun@uaq.mx

M. Rafael-Morales

Instituto Mexicano del Transporte, Querétaro, México  
mrafael@imt.mx

J. Cervantes-de-Gortari

Universidad Nacional Autónoma de México, México City, México  
jgonzalo@servidor.unam.mx

R. Colás-Ortiz

Universidad Autónoma de Nuevo León, Monterrey, Nuevo León, México  
rcolas@uanl.mx

**Abstract** Mexican history is full of interesting facts connected not only to social and political issues but also to engineering practice and technology development. This was the case with steam locomotives during the first half of the twentieth century. An essential means for the transportation of persons and goods, especially in a country with such a difficult terrain and agriculture land situation, railroad transportation played an important role on the years before and during the 1910–1923 civil revolution war. They also were essential to the conciliation and reconstruction times after the war, and to the industrialization in the years to come, supported by the foundation of the railroad workers unions and their outstanding participation in steam locomotives construction, as is reviewed in this paper.

The large railroad network expansion during the last and the first decades of the 19th and 20th centuries respectively, contributed enormously to set the beginning of the industrial growth of the country, in particular the iron industry, so important for construction and other productive activities. Nevertheless, those times were of social turmoil and effervescence that turn into a period of civil war among different revolutionary ideologies, mainly motivated by the need for a socioeconomic change, especially in the land ownership regime and the agriculture activities, with consequences to industry and commerce. The opposing armies used the railroad to move large number of troops from one region in the north to another region in the central part of the country, and vice versa. They also used the trains as for many strategic and support activities (noteworthy was the medical hospital-train in the army of Pancho Villa). Therefore, the railroads, the cars and the engines themselves were also the target to infringe important damages to a given enemy.

Once a new federal constitution was signed and the pacification of the country begun, there was a period of reconstruction and social renewal, especially in relation to industrial workers. Unions and the like organizations were founded and a new spirit of the working class settled in. The railroad workers participation was remarkable as they not only took part in the organization of the transportation companies but also in the equipment construction and technology improvements. This paper explores these experiences and facts that ended with the full design and fabrication of two large steam locomotives by a group of enthusiastic and well trained and organized railroad workers.

**Keywords** Railroads in Mexico, Locomotives

## Historical Review of the Railroads in Mexico

The railroad transport has played an important role in the socio-economic development of Mexico, given its orographical features, with large desert lands in the center and north of the country and jungle regions in the south, connected by huge and intricate mountains systems. It should be pointed out also that there are some cities at sea level and some of them up to 3,000 m above sea level, whereas distances, in the same direction, of more than 4,000 km.

The first complete railroad track in Mexico was inaugurated in 1873 joining Mexico City and Veracruz. The latter is an entry harbor in the Gulf of Mexico that has served for commercial, cultural and political interchange with Europe and the USA. The first constructions related to railroad activity actually started from 1837. Some workshops for foundry and mechanical construction were set at several places of the country. Clearly, the investments were minimal and even the low technology being used was imported. Nevertheless, it was recognized since then the importance that could have had the development of this mean of transportation.

With the economic difficulties, due to the lack of foreign investments, joined to the political instability and to the frequent foreign interventions, the construction of different railroads was very slow, until the culmination of the abovementioned

route (Mexico City-Veracruz). Actually, the infrastructure required for that railroad was an important masterpiece of engineering due to the terrain irregularities, including slopes of up to 5.5%. It required huge bridges and very sharp curvatures. This railroad was built by foreign and Mexican engineers. There were 26 steam locomotives (some of them with double boiler), mainly of British manufacture, with 200 different types of wagons. However, this first stage of the Mexican railroad was not problem-free. Indeed, the track beds were inadequate to the region's climatic conditions. Moreover, most of the locomotives lacked of the necessary power for the steep slopes as well as for the load being transported. Furthermore, most of the equipment was either, too old or, in bad shape. The facilities and workshops were provisional and had capacity only for minor repairs.

The railroad branching achievement in almost 30 years allowed to communicate the country from North to South, and much less from East to West, due to the orographical difficulties already mentioned. Thus, by the year 1880, the railroad network expanded to more than 1,000 km. However, the great impulse was given in the next decade, achieving approximately 12,000 km by 1890 and reaching more than 19,000 km in 1910. The North border and the Gulf of Mexico had thus communicated to the centre of the country via the railroad. In Emma Yanes-Rizo's words, "...The steam railroad changed the country's geography, the commerce, the production rhythm, the sense of time and the social relations" [1]. Parallel to the growing of the railroad network, and the concessionaries foreign enterprises, facilities and repair workshops also grew and they reached the technical capabilities for manufacturing steam locomotives in the country. Clearly, this was outside of the railroads enterprises.

Indeed, at the first stage of the great expansion of railroads, Government's policy was oriented mainly to foment by all possible means the construction of railroads tracks in such an extensive country and complex orography; even if this implicated enormous sacrifices and concessions that would favor investments. Clearly, this was a marketing integration with a fiscal regime favorable to the capitalistic development, in order to attract foreign investments for industry and commerce. At the second stage, the General Law for Railroads was issued and helped to regulate operations of the concessionaries enterprises, by stating some construction and equipping norms, oriented towards railroads modernization.

With the advent of the railroad in the second half of the XIX century, the railroad system was consolidated, as well as the agricultural and live-stock production in the great "latifundio" country state properties, a heritage from the colonial times (1521–1810). In addition, rules for the important industrialization, which reached its peak in the XX century, with the oil industry, great development of the hydroelectricity, and the highway network, were set.

During the colonial time, mining was also a very important economic activity. This led that at the second half of the XIX century Mexico stepped in towards its industrial development. Thus, several manufacturing companies were set, which used machines being powered by steam, like the same mining industry, textile, paper, sugar, shoe and leather, glass and steel industries, among others.

At the turn of the XX century, there was a remarkable urbanization, mainly in Mexico City, and an important industrial production with a diversified market and

self-sustained based on offer and demand. For obvious reasons, the steel industry was very important. At the beginning of the XX century, the company “Fundidora de Fierro y Acero de Monterrey” was started with a strong integration of iron and steel activities and a strong capacity (a furnace with a daily production of 500 metric tons, coke and several furnaces, rolling mills, etc.) for the production of several iron and steel goods, particularly useful for the development of railroads like tracks and also for building construction. The company had implemented the technological elements for the several stages for iron and steel production, starting from coke and iron mines extraction up to the finishing of steel profiles for structures. In addition of the high capacity furnace, it had also coke furnaces, steel furnaces, rolling mills workshops, all of them with a capacity of up to 1,000 daily metric tons. There was also equipment for pieces of cast bronze for self provisioning and to provide other industries. Facilities were in good condition for producing all the materials and equipment required for locomotives and passengers and load wagons.

At the beginning of the social turmoil (1910s revolution), the iron and steel enterprise had the capacity for producing tracks and accessories, but also the fabrication of locomotives and other specialized equipment as well. On the other hand, the Mexican transportation company “Ferrocarriles Nacionales de México” was more interested in the huge debt due to the recent nationalization, and very little interested in the possibility of investing in equipment fabrication inside the country, even though the important capacity in workshops and facilities of high technological level that had spread out in several places of the country. In other words, there were the given conditions for producing all the necessary material for a sustained development of this mean of transportation. However, the Mexican policy and economy were too weak to react to foreign pressure as well as the social internal conditions. There was not economic capacity neither political actions necessary to hold the economic development of a country pointing towards a railroad technological development.

The railroad network served as a mean of transportation for agricultural goods, merchandises and people, helping notoriously to the economic integration with the USA, but also to the communication and spreading of the liberal and social liberation ideas. Given the closeness of the USA and Mexico, the latter was taken as a place to perform espionage activities of the European countries, the USA, and Japan while the First World War [2] and the political revenge showing up along the XX century (for example the killing of Trotsky).

But moreover, railroads in Mexico played an important role in the Mexican revolution 1910–1917. This civil war among antagonist revolutionary factions was at first highly motivated by the need for a change in political issues. Thereafter a socioeconomic change was sought, especially in the land ownership regime and the agriculture activities, with consequences to industry and commerce. The opposing armies used the railroad to move large number of troops with horses and

cannons, from one region in the north to another region in the central part of the country, and vice versa. They also used the trains as for many strategic and support activities: Noteworthy was the medical hospital-train in the army of Pancho Villa [3]. Therefore, the railroads, the cars and the engines themselves were also the target to infringe important damages to a given enemy (Figs. 1, 2 and 3).

## The Railroad Union in the Post-Revolution

The first railroad unions emerged since the last decade of the XIX century and were consolidating in the previous years to the starting of the revolution of 1910. Some organizations of important workers' unions had been settled through the continuous search for better working conditions, before the military fight. Besides, they struggled for having access to education and technical training for workers. This would allow them to get working places being occupied for foreigners, which represented a strong brake for workers improving. These two last aspects were very important for the posterior workers' rights, and also in the development of technological and management skills for managing railroads companies. Close to the end of the "maderista" stage (1910–1913), the railroad workers achieved, through a strike, several labor reinvidications, above all in relation with the technical training and the right to occupy higher hierarchical jobs. But, because of the revolution, the above implementation was stopped and workers had to learn authentically "on the walk" for developing their creativity and any other skills; these were converted actually in surviving requisites.

The military war between antagonist groups affected strongly the quotidian life and working relations in the railroads working class, many times originated for the lack of technical knowledge of the militaries of intermediate rank and the power they exerted. In the new phase of the fight, trains were strategically and tactically important. Those who controlled and dominated the tracks and the trains had extraordinary offensive and retractile capacities. The mechanical and railroad destruction/construction was commonly practiced. The revolutionary "guerrilleros" and their commandants had taken the power of the railroads. The above resulted in enormous difficulties for railroads workers, especially for the machinists and operators. War divided the most skilled workers, who were the most valuable for the revolutionary bosses. As a consequence, the fidelity to "caudillos" and the campaign successes substituted the requisites of salary scale, anciently, and knowledge for workers. In the workers jargon, this gave rise to the so-called "carabina rights", as pointed out clearly in [1].



**Fig. 1** Military train (ca. 1910)



**Fig. 2** Military train (1913)



**Fig. 3** Military train (ca. 1914)

Once a new federal constitution (1917) was signed and the pacification of the country begun, there was a period of reconstruction and social renewal, especially in relation to industrial workers. Unions and the like organizations were founded and a new spirit of the working class settled in. The railroad workers participation was remarkable as they not only took part in the organization of the transportation companies but also in the equipment construction and technology improvements.

With the triumph of the constitutionalist revolution, the railroad management went back to the hands of the State and the system had new challenges. On the one hand, the tracks, locomotives, and rolling equipment reconstruction, and on the other hand the workers organization.

During Álvaro Obregón's administration (1920–1924) the institutions raised from the revolutionary upholding started to consolidate, namely, the class alliances, the strong presidential role and a capitalistic model with strong State's participation, who survived up to the decade of 1980. The revolutionary chiefs privileged to their closest collaborators with public jobs, especially those from the railroad company: it was part of the politics and the same time a military tactic, a fashion for body guarding. The country pacification was not yet complete and the railroads continued being strategic for controlling the frequent military rebellions and to keep the communication with the North border.

The railroad traffic was resettled and it was oriented to the activity of workers for repairing and track reconstruction, bridges, train stations, and workshops. Wagons and locomotives were purchased (it was acquired what the US wanted to sell). The equipment had to be readapted according to the needs of the country; locomotives of wood for coal; from coal for oil, etc. Domes, mechanisms, valves, etc., were changed in order to function according to the geographical characteristics of the divisions to which they were assigned. Nevertheless, the contracts signed with private companies for repairing and reconstruction of wagons and locomotives do not have success because they were no exempt of speculation between concessionaries and state officers; corruption and bribing; and few personnel being hired. The above rose, among other things, the lack of significant investments in workshops of the national railroad company, thus these were underused. Because of the above, the railroad dependence with the USA increased with important effects on the amortization of the debt and the management of enterprises. Anyway, parallel to equipment renovation and administrative reorganization of the company, the railroad activity increased and also the diversity of the job functions. In the workshops, the learning was given in the master-pupil relation, thus increasing the importance of the mechanical master.

The period 1924–1929 of president Calles' administration, the political stability was broken several times (Huerta and Escobar rebellions, "Cristeros" war, Serrano's plot, and the murder of Obregón). The crisis was stopped with the foundation of the PNR (PRI antecessor) as a first step to build a system that would allow to pacifically find a remedy to the presidential succession. The PNR was centered in the conciliation and national unity and the execution of two of the most important articles of the 1917s constitution.

On the economic viewpoint, the State participated actively in the industrial development without stopping the growth of the national burgess. The railroad



company was given back to foreign private companies (1928) with the control of the 51% of assets belonging to the government, etc. Several agreements were signed with the railroad sector. The railroad debt was separated from the public debt. The company had a modern organization structure and the main preoccupation of the investors was the reorganization of railroads. Adjustments on salaries, tariffs and expenses in order that the company could satisfy its financial obligations were made. The policy of the company was oriented neither to the purchase of new rolling material, nor to the locomotives repairs in private shops, but the foreign rent of locomotives and wagons continued. With the growing of the company, an internal complex organization of the working process was also developed. This was due to the multiplicity of professions and specialties demanded by the railroad growing. The mechanical workers were in intimate contact with the locomotives. They were highly trained, with a great experience, and a deep knowledge regarding to the functioning, reparation and reconstruction of machine tools and rolling materials. To move up in the ranking was regulated besides the corresponding boss, by a real knowledge of technical matters.

The Lázaro Cárdenas administration (1934–1940) modified the orientation of the Post-revolution development already set by the previous regimes. Indeed, a nationalist policy was set as the leading direction. The local “cacicazgo” was eliminated and turned back to centralize the power at the presidential figure. It searched to achieve the two main revolution’s objectives, namely, the agrarian distribution and the workers’ rights. Workers and agricultural groups were motivate to organize and make use of the strike to defend their rights and make a front against national and foreign investment, giving rise to one of the politic-economic most important nation’s event: the oil expropriation. However, the pretension of the oil union to administrate this resource was unaccepted.

It was not the same with the railroads. In 1937, the government nationalized them, with the corresponding indemnification to the companies, so to say, recognizing its debt. The measure was apparently too radical, but the railroads being nationalized were those broken and the State trying to liberate of them, left them on workers hands. The delivery of the company to the workers implied autonomy to reorganize it as a State’s decentralized dependency; workers would be the administrators, but not the owners. The Government thus tied the new administration’s hands leaving the whole debt during nationalization. Moreover, the State make no investments, nor loans; neither collaborated with the debt’s payment. Instead, inappropriate concessions were given to mining companies related to the prices of loading mining being transported: less than 50% of the actual transport load cost. Devaluation, and wagons and locomotive rentals increased the foreign debt. The economic difficulties forced the company to stop salaries increases causing grievance among workers. The economic situation of the company was a disaster because it could pay only half of the invoices with a serious deficit of equipment and locomotives.

In the period 1940–1946 when Manuel Avila Camacho was in power, the system of only a single political party was getting consolidated, all of the different ideological trends were discussed inside that party. The Government got farther of the proposed original plans, favouring more to the party’s right wing and allowing



the conformation of a capitalistic economy, with State intervention, but with a diminished participation of the workers organizations and their socioeconomic demands.

All of the above was given in the frame of the Second World War, in which Mexico was with the allies and declared war to the Berlin-Rome-Tokyo axis. This situation encouraged an accelerated economy growth, with high demand of Mexican goods and an increase in industrial production. The State support was given basically to manufacturing and transformation industries, but not to transport, where investments were destined more to the widening and improvement of roads and the purchase of automotive vehicles.

Even though the investments and widening capacities of the railroad network was limited during that period, an intensive use of the railroads was achieved, with an increase of the transported load. This was the result of an important stage of negotiations between workers and the company, which in 1941 was constituted as a decentralized State company. To this contributed the spirit of national unity that prevailed in that epoch, the collective effort of workers and the attitude of the administration of railroads for listening the union demands, particularly those related with the need of repairing and building new locomotives at the company's workshops and not in the USA.

## **The Workers' Technological Creativity**

Railroads workers' union besides having played an essential role in the fights for labor rights in Mexico, it also implied a technological development, given the workshop activities, transportation and commerce that this sector signified for the economy of the epoch. For the year 1935 the only one railroad workers union had about 35,000 workers. They served as a technological structure, and therefore socioeconomic, for the workers turmoil that there were in the reconstruction and development of the country. The experiment of the workers' administration lasted two years and a half and the company could not get rid off of its heavy load debts. Very often the workers' administration is minimized albeit their efforts for making it theirs and developing their labor creativity. During this period, there were big efforts to come back to the personnel training and modernization of workshops for eliminating contracts for performing repairs outside the company, and rolling material rentals as well. The benign results rose and by the end of the year 1937 several locomotives had been reconstructed and also the starting of the fabrication of the first passengers wagons. To the initiative to modernize facilities and workshops, followed a policy of support to labor creativity with several interesting technological results, going from novel designs and more economic mechanisms for the operation locomotive's boiler, up to safety devices for locomotive combustion.

The development of the capacities of railroad workers had its origin in the railroad expansion at the second half of the XIX century. This was so, because many railroad workshops masters came from the epoch' artisans workshops. In these

workshops, they had acquired the experience for working with iron, foundries, wood, etc., and some of them had the knowledge in mechanical work from the mining workshops and the textile industry. With the coming of railroads, they encountered new devices and tools that had to learn by developing their capacities and take advantage to the diversity of machines being in front of them. The trained personnel were in charge of teaching new workers within the traditional structure of the artisans' workshops. The same happened with the jobs for handling the locomotives. Indeed most of the machinists were foreigners and there was a continuous fight that motivated workers since the first organizations demand the work training and the nationalization of the railroads. So, in 1907, the first training schools were open. This was a fundamental requisite in order to substitute the foreign personnel. Several books on diverse themes were written for helping to the workers' training. For example, in [4] were presented several aspects from design and construction of boilers, pressure recipients, domes and fire tubes, with definitions and parameters of geometry, tanks construction and reservoirs; physical principles of locomotives operation; several mechanisms used in the machines, types of fuels, and the like. Throughout these books the monopoly of knowledge ended and the traditional training fashion via master-pupil. The union's organization also contributed to the spreading of knowledge via its newspapers and gremial publications (Figs. 4, 5, and 6).

## **Locomotive Construction in Acámbaro's Workshops**

A history, very little known, was the goal from the union organization about the possibility to contribute to the technological development of the national railroads by manufacturing in the country steam locomotives to propel its growing. In the city of Acámbaro (Guanajuato), especial conditions were given that would had favored a development in this sense, as described in [5], because it was a joining place of the railroads between Mexico's central plateau and the Pacific Basin, since 1883. Given the different tracks' widths joining there, it was necessary the change of merchandises from one system to another. The railroad station had a large patio for maneuvers and a round workshop with capacity for width and narrow tracks locomotives. Thus, Acámbaro was converted in a very important railroad center given its geographical situation and its workshops with machine-tools and furnaces of adequate capacity.

Even the closeness of Celaya and Leon, region where several battles took place, and in which Obregón fought against Villa, thus insuring the final triumph to the moderated wing of the revolutionaries, in Acámbaro there were neither rapping nor important battles, the railroad facilities were undamaged and the workshops kept machinery and tools from the pre-revolution times. In the following years there were not new locomotives, but none of the assigned to that division was lost.

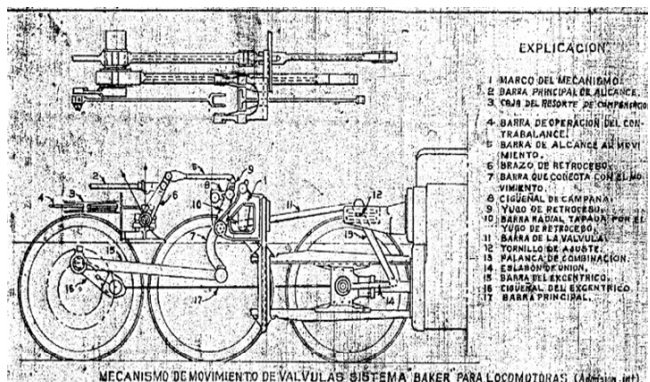


Fig. 4 Locomotive valves mechanism (Source: Acámbaro’s Museum)

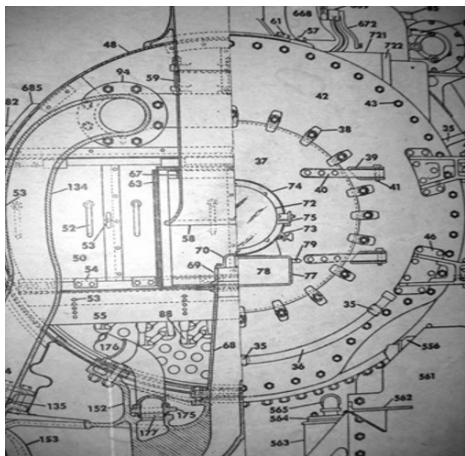


Fig. 5 Locomotive drawing (Source: Acámbaro’s Museum)

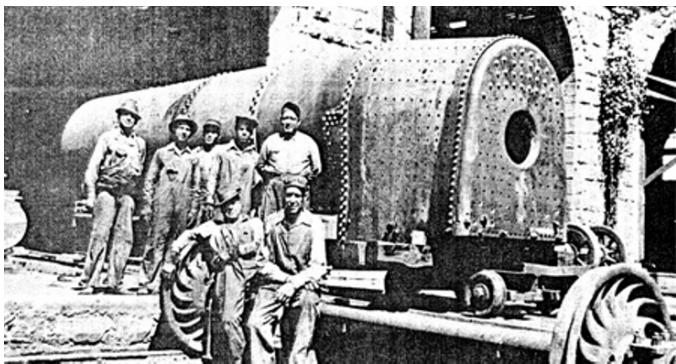


Fig. 6 Locomotive shop workers (Source: Acámbaro’s Museum)

Thus, Fidelita—nickname given to the locomotive by the railroad workers in remembrance of the dead girl of the company's managers—and “her sister” were born. Two locomotives wholly built at Acámbaro's workshops. Fidelita still exists and it is placed as a landmark at Acámbaro's Railroad Museum; her sister was dismantled. The fact exemplifies how the workers organization was able to hit into the organization structure of a national enterprise to set the basis for a plausible technological development.

The locomotive 295 was inaugurated in September of 1942 (Fig. 7). This was a product to a large process where the characteristics of Acámbaro's workshops, their workers, and the national railroad company were mingled, but above all, a great collective willingness effort. The initiative for building the locomotive in Acámbaro was due to the master José Cardoso, who struggled for producing new locomotives with improved traction with respect to the rebuilt ones and because in those workshops there were a wide experience in reconstruction and repair many locomotives in the previous years.

The construction was done under engineering procedures and the supervision of the workshops' mechanics workers, with compromises for the participants workers that can be resumed in the fulfillment of ordinary work with the same personnel and same time schedule with extra hours assigned to foundry's personnel, mechanics workers, warehouse, and design of the Acámbaro's workshops, only for two months.



**Fig. 7** Inauguration of 295 engine (September 1942)

The construction of the locomotive 295 caused a great deal of enthusiasm among Acámbaro's workshops workers, who immediately proposed that two more locomotives were built, with the possibility of producing them in series. Their main argument was that the fabrication time would be reduced from 150 days to only 20 days, thus avoiding to import new locomotives from the USA. The company accepted the construction of only one more locomotive: the 296, baptized as Fidelita (Fig. 8). The main technological changes were overheated steam, the use of a Stephenson mechanism for opening the valves, and the substitution of bushings by roller bearings.



**Fig. 8** “La Fidelita” in Acámbaro’s museum (today)

Years 1942–1944 were little favorable to the workers union, especially in their requests related to productivity and construction of rolling equipment. This period coincides with the peak of the Second World War. Mexico’s compromises with allies were, for the national railroads, among other things, to assure the load traffic towards the USA, and the creation of war cooperation commissions. These were integrated by members of the union and the company, organized in such a way for guaranteeing an increase in production and efficiency in the services, in a similar fashion as the commissions in US factories, through the War Production Board. The workers’ effort allowed the increase in productivity and the fulfillment of the abovementioned compromises. When the war ended, Mexico had become part of the modern capitalism, with an annual economic growth of 7% in the period 1940–1945.

By the end of 1946, Miguel Alemán became the new president. At the beginning of this administration, the automotive industry was supported rather than the railroads. This automotive industry, with mostly foreign investment, started the production of trucks. In turn, in the railroad sector, the company’s policy was oriented towards the change of narrow tracks to wider ones and the acquisition of diesel locomotives, in a process that should have been slow for the adequate workshops technological adaptation and the technical personnel. Nevertheless, it was carried out in a quick way, thus discarding the technological experience of many workers and condemning prematurely to many steam locomotives to the trash.

As pointed out by Yanes-Rizo [6], it makes no sense talking about history of the scientific or technological contributions in a society, if these are not linked with the social environment where they are developed.

## Conclusions

The manufacture of locomotives in Mexico emerged as the result of a process in which several circumstantial aspects were mingled: the experience acquired in the continuing repairs of locomotives in national workshops during the period of the



social revolution; the organization of railroad workers and, in particular the insistency of Acámbaro's workers, who fought for technical training and the construction of rolling equipment in their workshops; the diverse agreements between the enterprise and the union in the period of the II World War, that made possible the organized development of the creativity and the enormous labour capacity of Mexican railroad workers. Having lived in difficult times, where violence and scarcity and the direct exposition to warlike actions and their effects, including the lack of materials supply and technological knowledge, evidently influenced in the generational surviving of the Mexican railroad workers. Thus, the history of science and technology in a country as Mexico, is also an economic and political history, it is the history of its dependency and its inhabitants' creativity, their needs and proposals, their advances and obstacles, of the working people and their people in the government. The necessary link of the technological evolution with the country socio-political structure and the history of workers and their working fashion in a certain period, makes it possible a social history of the technology. It is indeed, a history of men related to machines. Machines lack of history, except in their relationship to men, to the workers and the context where they were produced.

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